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Design of an Adaptive Persuasive Mobile Application for Stimulating the Medication Adherence

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Abstract. There is a variety of persuasive applications that have been proposed in different application domains like well-being, health-care and e-commerce. However many have been designed largely for a general audience. Designers of these technologies may achieve more success if applications consider contextual information of the user for making them more adaptable. This paper is an proposal for improving medication adherence by sending personalized persuasive message and reinforcing feedback. To do this, we propose an adaptive services oriented architecture, and a persuasion strategy defined for selecting the appropriate persuasiveness level according to contextual information such as time and stress. Stress measure is derived from physiological data (e.g. Electro Dermal Activity, heart rate, temperature), which is collected through a wearable wireless multi-sensor device.

Key words: medication adherence, persuasive message, stress, fuzzy logic, inference system

1 Introduction

The World Health Organization[1] (WHO) ensures that the failure of the medical treatment is the main cause that has not obtained all the benefits that medicines can provide patients [1]. In consequence the poor medical adherence carries medical complications, psycho-social and economic in the person and society. It reduces the quality of life due to the complication of the disease and the use of more potent drugs, depression and in the worst cases, death. This is why the importance of generating new strategies that fit the patient's needs for stimulating medication adherence. For instance, a health-care game using a robotic assistant was proposed by Gonzales *et al.* [2]. Kamal *et al.* uses text persuasive messages for reminding when to take the medicine [3]. The specific content of the persuasive message is derived based on the Social Cognitive theory and Health Belief model. In contrast to our approach, authors do not consider different persuasiveness levels and reinforcing feedback. Moreover, both approaches do not

[1] http://www.who.int/en/

take in to account internal context information of the user (i.e. physiological data), which can be used not only for providing personalized and adaptive messages but also for monitoring heart rate or skin temperature. We also find other related strategies such as counting of pills, electronic control, telecommunications systems for monitoring and counseling and care equipment [4] [5].

With the increasing power of mobile phones and the recent technological advances in non-obtrusive and ubiquitous monitoring technology, in this article, we propose an architecture of a context-aware mobile application that exploits real-time physiological data for delivering self-adaptive persuasive messages that stimulate the medication adherence. We will use the E4-Wristband[2]; a wearable wireless multi-sensor device for real-time computerized biofeedback and data acquisition. The paper is organized as follows, in section 2 we present our adopted persuasion strategy. Section 3 describes the main components of our architecture. Finally, conclusions and future work are discussed in section 4.

2 Persuasion strategy

Cialdini [6] developed six principles of persuasion(i.e. Reciprocity, Commitment and Consistency, Social Proof, Authority, Liking and Scarcity), which have been successfully applied in different domains, such as e-commerce [7] or well-being [8]. Based on these six principles [6], we identify four levels of persuasiveness as the most appropriate for stimulating the medication adherence:

1. **Scarcity (Level 1):** When something is scarce, people will value it more (e.g. I believe rare products (scarce) are more valuable than mass products).
2. **Consensus (Level 2):** People do as other people do. When a persuasive request is made people are more inclined to comply when they are aware that others have complied as well (e.g. when I am in a new situation I look at others to see what I should do).
3. **Commitment (Level 3):** People do as they said they would. People try to be consistent with previous or reported behavior, resolving cognitive dissonance by changing their attitudes or behaviors to achieve consistency. If a persuasive request aligns with previous behavior people are more inclined to comply (e.g. I try to do everything I have promised to do).
4. **Authority (Level 4):** When a request or statement is made by a legitimate authority, people are more inclined to comply or find the information credible (e.g. I always follow advice from my general practitioner).

The hierarchical ordering of persuasiveness levels is defined based on the findings reported by Kaptein *et al.* [9], who found the authority and commitment principles as the most influential, and scarcity as the least. We adopt also the liking principle ("People prefer to say *'yes'* to those they know and like" [6]) because it is easier to obtain changes of attitude, by using personalized messages at all persuasiveness levels. We consider that these messages, emitted by people

[2] https://www.empatica.com/e4-wristband

that care-giver knows and likes, will be more friendliness for the care-receiver to improve his/her medical adherence.

The mobile application emits an alert message (non persuasive message) "X" minutes before for alert to user that is time to take the medicine. "X_1" minutes after to take the medicine the mobile application will emit persuasive messages, which can be generic or personalized.

Figure 1 illustrates how the variables of stress and time are used as main inputs for rendering messages with different levels of persuasiveness. For instance, if a high stress level is detected, then a level 4-persuasive message is rendered. Whereas having a medium stress level, messages of level 2 or level 3 can be emitted.

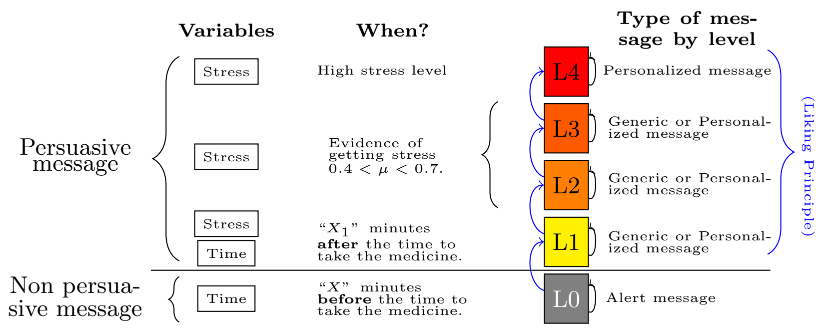
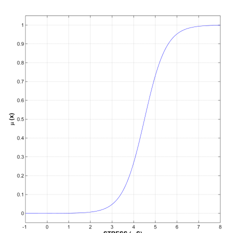


Fig. 1: Strategy for delivering adaptive persuasive messages

We use fuzzy theory for representing the Stress level as a linguistic variable. The Figure 2(a) shows the graphic of this function and the values of our sigmoidal membership function is defined as Figure 2(b).



(a)

$$sigmf(x, 2, 4.5) = \frac{1}{1 - \mathrm{e}^{-2(x-4.5)}}$$

(b)

Fig. 2: (a) Graphic of membership function. (b) Sigmoidal membership function for Stress linguistic variable.

Where $x \in [-1; 8]$, this interval of values corresponds to the scale of the EDA (Electro Dermal activity) sensor (using E4-Wristband). The unit is measured in microSiemens (μS). According to Ollander et al [10], the presence of stress is considered when the EDA value is $\geq 4.5\mu S$.

In order to adapt the persuasiveness level and time interval, we design an inference engine based on the Adaptive Resonance Theory (ART) [11]. ART is an unsupervised learning method that allow to retain previously learned knowledge and simultaneously integrate new discovered knowledge. Moreover, ART compared to other type of classifiers require less training effort (usually less than 20 epochs) [12]. Thanks to the ART algorithm, our approach will be able to render adaptive persuasive messages by using as main input the outcome of the sigmoidal membership function defined for the stress. This way, we avoid that messages become monotonous for the user (care-receiver) by changing the level of persuasiveness and type of messages.

Therefore, our messages catalog is classified by persuasiveness level and type of messages (i.e. generic and personalized). The generics will be given by default and the personalized messages are those messages, whose content is defined by care-givers (i.e. family member). The table 1 illustrates some examples of persuasive messages.

Table 1: Persuasiveness messages catalog.

Level	**Type**	**Action**
L4: *Authority*	Personalized	1. Emit Message: "*Mom should take the pill for you're well.*" 2. Send a text message to the phone of doctor or relatives close with authority, indicating that the patient is not in compliance with the prescription.
L3: *Commitment*	Generic Personalized	Emit Message: "*Remember that improve your health is your goal.*" Emit Message: "*Grandma should take your pill remember that you committed to improving your health.*"
L2: *Consensus*	Generic Personalized	Emit Message: "*All people care about their health and you too!.*" Emit Message: "*Grandma takes her pill every want that you are well.*"
L1: *Scarcity*	Generic Personalized	Emit message: "*Your health could worsen if not take their medicines.*" Emit message: "*Grandma takes her medicine for that you can still visit her friends.*"
L0: *Notification*	Non persuasive	Emit message: "*It's time to take the pill.*"

3 Adaptive persuasive mobile application architecture

The Figure 3 depicts the architecture and main components of the persuasive mobile application. On the left side, there is the care-receiver, who would wear a E4 wristband, an smartphone with the application running on it, and, optionally, a bluetooth wearable speaker hanging on the lapel or any other suitable place according to user conditions. The wristband has several sensors embedded that provides readings about stress measures (EDA), heart rate (Photoplethysmography), and physical activity (3-axis accelerometer) and skin temperature (Infrared thermopile). The data gathered in run-time is submitted to the smartphone via bluetooth.

The application basically consists of a messaging interface that is able to i) make use of the feedback user interface to render persuasive messages and

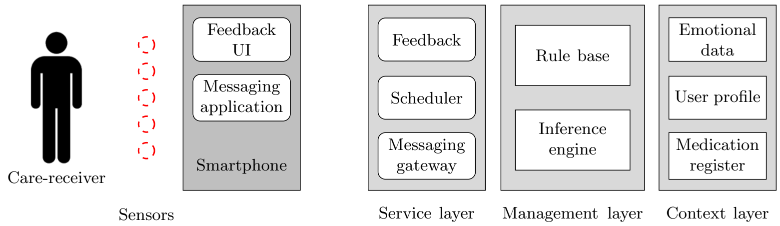


Fig. 3: Persuasive mobile application architecture

reinforcing feedback to care-receiver; and ii) push messages targeted at care-givers. The rendering of messages can be done in text and/or in audio form, depending on a format header associated to each message.

On the right side, there are the different service layers to support the working application. The primary service layer is the one responsible for the direct communication with the application. It basically contains a messaging gateway, which is able to reach recipients (e.g. care-givers and care-receivers) and deliver messages. The Scheduler controls when messages should be delivered and re-transmitted again provided by the Feedback service. The messages are configured following the persuasiveness strategy described above, which is implemented by the services in the Management layer. This also uses the Context layer, which maintains the relevant context data for users, including the historical information.

4 Conclusion and future work

In this paper we present the architectural design of an adaptive persuasive mobile application for stimulating the medication adherence. The purpose of the application is to provide the most effective reminder service by means of using adaptive persuasive messages. We argue that this adaptation is possible by exploiting physiological data in order to adjust the different persuasiveness levels at run-time. Based on the six principles of persuasion proposed by Cialdini, we have defined a persuasion strategy by identifying four different persuasiveness levels and proposing a catalogue of types of messages; which can be generic and personalized. Another important contribution of our approach are the evaluation rules defined for determining the stress and the persuasiveness levels, as well as the decision rules for selecting the most appropriate persuasive message (management layer). As part of our future work, we are going to validate the prototype of our adaptive persuasive application in two different stages. First, we plan to conduct a series of simulation-based experiments to assess our inference rules. Then, we plan to conduct a single case-base experiment for evaluating the effectiveness of persuasive messages delivered by our prototype application. Our case is a patient with hypertension (83 years old), who will use the wearable and wireless E4 Wristband device for collecting real-time data in her daily life and long-term settings.

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